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Ferroelectric Ceramic Plasma Source Development

A ferroelectric ceramic plasma source is under development at PPPL to serve as a source of beam-neutralizing electrons for ion-beam drift-compression experiments at LBNL. The goal is to produce a dense, cold plasma without introducing neutral gas or magnetic fields that would interfere with propagation of the ion beam.

Ferroelectrics, such as the barium titanate used here, are well suited for this application because they have dielectric coefficients of 1000 or more. When a high-voltage pulse is applied across such a material, the polarization surface-charge density that is induced on the surface can be large enough to create electric fields that ionize the material, thus creating a plasma.

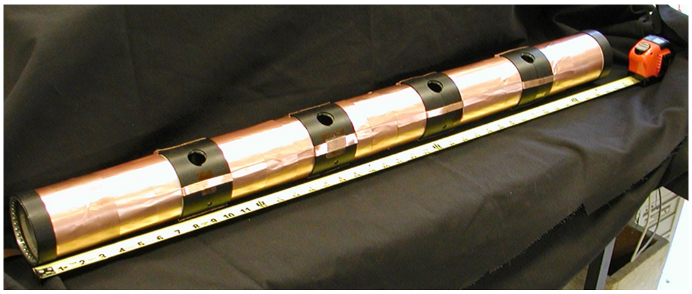
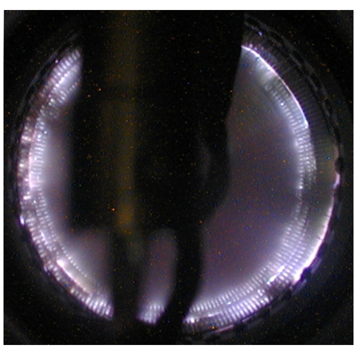


FIGURE 1. Five separate ferroelectric ceramic plasma sources are connected to form a one-meter-long plasma source.

A series of 3-inch diameter barium titanate rings with a metal film on their outer surfaces are stacked together to make five 20-cm-long plasma sources. The five sources are then connected into a one-meter-long plasma source, with access points for diagnostics between each pair (see Fig. 1).



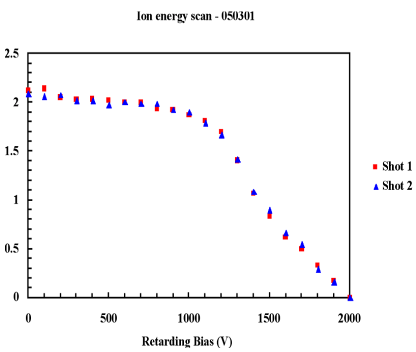
The inner electrodes are made from perforated steel sheet; it is in the "microgap" between the perforated steel sheet and the barium titanate where the electric field becomes large and plasma formation occurs when a high voltage pulse is applied between these electrodes. The plasma then fills the interior of the device (see Fig. 2).

FIGURE 2.
A time-exposure photo of 24 pulses shows the plasma emission from from the wall. The view is partially obsured by the voltage lead in the foreground

Initial measurements show that the plasma density is ~10^{10} cm^{-3} and that the electron temperature is ~15 eV for ~10 µs, after which the plasma has mostly dissipated. Tests are currently underway to characterize the behavior of the plasma source. The axial and radial density and temperature profiles, as well as their temporal dependencies, are being studied. ***– Erik Gilson***

Retarding Potential Analyzer measures beam neutralization

A Retarding Potential Analyzer (RPA) was designed and inserted between quadrupole magnets 1 and 2 of the high-current experiment. This detector consists of three grids, and a collector that is connected to a charge sensitive preamplifier (CSP). The preamplifier can integrate a small burst of current, producing an output that is proportional to the total charge collected. The RPA can be biased to measure the energy distribution of either ions (figure 1) or electrons produced.



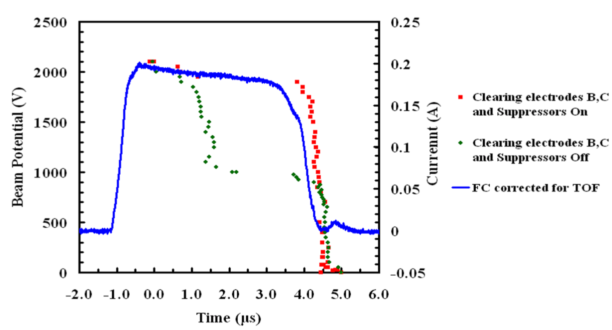
The ionized gas expelled by the beam potential can also act as a probe giving the information of the beam potential neutralization. With a series of shots at different

FIGURE 1 Ion energy distribution measured

retarding potentials, we can determine the dynamic beam potential.

Figure 2 shows the dynamic beam potential measured for two different setups. The beam potential (red squares) has the same slope of the Faraday Cup current, so there was no significant neutralization. The green circles give 43% neutralization, accomplished by permitting electrons from the end wall to drift upstream.

FIGURE 2 Dynamic beam potential measured



The electrons generated from ionization and interaction of the halo with the walls can accumulate during the beam, being expelled at the end when the beam potential drops. The amount of electrons expelled constitutes an independent measurement from electron accumulation. A problem arises during this measurement, because at the same time that we expel the electrons the beam tail scrapes the wall and desorbs electrons, giving another source of electrons that cannot be distinguished from the neutralization. Some new experiments have been discussed to eradicate this effect.
– Michel Kireeff Covo

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